Design and Development of a Generic Architecture

for

APPAREL MANUFACTURING ARCHITECTURE
[Version 1.5]

Volume I: AMA Primer

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Research has been carried out to design and develop a generic architecture for an apparel enterprise that can serve as a blueprint for a computer-integrated apparel enterprise (CIAE). The Apparel Manufacturing Architecture (AMA) -- the first comprehensive architecture for manufacturing -- has been developed and validated in close collaboration with the apparel industry. AMA consists of a set of models the core of which is the *information* model which defines the schema of the shared information base for an apparel enterprise. The *function* model component of the architecture specifies how the activities carried out in an apparel manufacturing enterprise interact with each other through the shared information base. The third component of AMA, the *dynamics* model, describes how the interactions among the enterprise activities take place over time. The Recruit Induction Center Architecture (RICA) models the uniform distribution process at the Recruit Induction Center (RIC).

Volume I introduces the modeling techniques used in developing AMA.

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PREFACE

The Apparel Manufacturing Architecture (AMA) is a comprehensive set of specifications for a Computer-Integrated Apparel Enterprise. The research on the development of AMA began at Georgia Tech in July 1988; it is being funded by the US Defense Logistics Agency. Oxford Slacks in Monroe, Georgia, was the first industry partner actively collaborating in the initial development activities. Subsequently, several member companies of the American Apparel Manufacturers Association (AAMA) participated in reviewing and enhancing the draft version of AMA. In October 1992, Version 1.0 of AMA was released in two volumes; the first contained the Function and Dynamics Models while the second contained the Information Model.

To test and validate AMA in the real-world, two plant implementations were successfully carried out with the active collaboration of Dowling Textiles of McDonough, Georgia, and Terry Manufacturing of Roanoke, Alabama. Just as continued maintenance, updating and support are essential for any acquired technology to have a long and meaningful impact, AMA has been reviewed regularly and opportunities for enhancing it identified. To formalize this enhancement process, a two-day Workshop was convened in April 1994 in which experts from industry, academia, research laboratories and government agencies participated. At this Workshop, AMA was reviewed in-depth and areas for enhancing it were actively discussed. The results from the Workshop have been used to create this version of AMA, Version 1.5.

AMA [Version 1.5] is being released in three volumes: Volume I: AMA Primer; Volume II: The Function Model; and Volume III: The Information Model.

Volume I introduces the modeling techniques used in developing AMA and provides an overview of AMA. It is intended to serve as a guide to understand the Function and Information Models in Volumes II and III, respectively. Volume II contains the Function model along with a glossary of terms used in the model. Likewise, Volume III contains the Information model along with the respective entity definitions in AMA. In addition, it contains a table of all the entities and their attributes. For each attribute, its SQL "attribute type", e.g., Character, Numeric or Date, is defined.

As with any such major research effort, the active participation of several individuals and organizations led to this architecture and their contributions are thankfully acknowledged (please see Acknowledgments for complete listing). Any comments on AMA including suggestions for enhancements are welcome.

Sundaresan Jayaraman
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CHAPTER I

INTRODUCTION

The objective of this research is to develop an architecture for an apparel manufacturing enterprise that will serve as a blueprint for implementing computer-integrated manufacturing (CIM) in the apparel industry. Although computer-based tools have been developed and used in the apparel industry to enhance the productivity of individual functional components of the apparel enterprise, these efforts have not been part of an overall scheme of *integration*. As a result, most enterprises operate with incompatible subsystems which cannot share information with each other. The current work is a maiden attempt at creating a systematic integration architecture for the apparel manufacturing enterprise.

The functions and structure of an existing representative apparel enterprise have been studied and represented using descriptive modeling techniques. The resulting AS IS model has been analyzed to understand the integration needs of an apparel manufacturing enterprise. The results of the analysis of the AS IS model have been used in conjunction with advancements in information technology to create the TO BE architecture for an integrated apparel enterprise, i.e, the Apparel Manufacturing Architecture (AMA).

The apparel manufacturing architecture (AMA) is a comprehensive set of specifications for a computer-integrated apparel enterprise. AMA consists of a set of models, the core of which is the *information* model which can be used as the basis for an enterprise-wide information system. The *function* model component of the architecture specifies how the activities carried out in an apparel manufacturing enterprise interact with each other through the shared information model. The third component of AMA, the *dynamics* model, describes how the interactions among the enterprise activities take place over time and is critical for simulating the operations of the enterprise. AMA encompasses activities spanning product development to distribution of finished goods.

1.1 An Overview of Apparel Manufacturing

Apparel manufacturing enterprises differ in size and complexity from small contract sewing shops to large corporations with their own design studios and product lines. The typical enterprise modeled here carries out activities ranging from design to distribution of garments according to customers'* specifications. At the top level, the functions of such an enterprise may be classified as follows:

1. Marketing, Product Development and Sales
2. Planning and Preparation for Production
3. Manufacturing
4. Customer Service
5. Distribution
6. Engineering and Quality Control Services

The *marketing, product development and sales* functions cover all the activities performed before production orders are finalized. The enterprise works with the customer to develop garment styles according to customer's specifications. For private label products, the sales staff negotiates the contract with the customer for orders on garments that have been developed. This contract provides general terms of agreement between the enterprise and the customer; however, it does not contain *all* the details such as color/size distribution of garments which are specified closer to delivery dates so that the customer can utilize the latest point of sale (POS) data to order those garments that are being sold.

The central coordination point for all the activities after a sales contract has been signed is the *customer service* function. It interacts with the customer on a regular basis and issues the production orders to the enterprise for meeting the customer's order requirements and schedule. It is the responsibility of customer service to ensure that the distribution system has the appropriate finished goods to ship to the customer when the customer sends the shipping orders.

The *manufacturing* function services the distribution function by supplying the finished goods. The *planning and preparation for production* function, in turn, services the manufacturing function by scheduling production and making raw materials available. The *engineering and quality control services* functions are auxiliary functions providing services to other functions. The en-

* Customer is defined as a retailer or an individual end user (consumer).

terprise, as a whole, can be viewed as a provider of goods and services to its customers. The customers include chain stores, outlet retailers and mail order houses.

An important characteristic of a majority of the apparel manufacturing enterprises is that they do not produce to meet projected sales. The enterprise should be prepared to produce goods at very short notice if it has to produce to firm orders. The customers desire the flexibility of making their buying decisions as late in the season as possible. Even when sales contracts have been signed for the whole season, the enterprise does not know the specifics such as size and color distribution well into the season. The raw material (fabric, trim and accessories) suppliers play a critical role in the enterprise's ability to manufacture goods at short notice.

The operations of a typical apparel enterprise are spread over a vast geographical area. The styling studios and marketing operations are located close to fashion centers, such as New York City, Dallas and Los Angeles. Manufacturing facilities are generally located in areas where inexpensive labor is available. Product development, pattern and marker making, and cutting are carried out in centralized locations which support numerous sewing and finishing plants, some of which are located overseas. Distribution of finished goods is carried out from a central location.

1.2 Need for Apparel Manufacturing Architecture

Process mechanization and information systemization are the two main facets of CIM. In a discrete part manufacturing enterprise, a considerable part of the effort that goes into manufacturing is expended outside the boundaries of individual processes -- in information processing tasks involved in coordinating these processes. In such an enterprise, the benefits from process mechanization are limited if process mechanization is not accompanied by an appropriate level of information systemization. Until recently, the efforts of the apparel industry in advancing the state-of-the-art in apparel manufacturing have primarily been directed towards process mechanization, with very little attention having been paid to the information systemization aspect. Before integration can be attempted, there is a need to understand and document how an apparel enterprise operates so that the information sharing needs of the enterprise can be understood and defined. The objective of this research effort is to understand the operations of an apparel enterprise and develop an architecture for a CIM system for apparel manufacturing.

Moreover, the US apparel industry's approach to competition has shifted from a cost-

based approach to one based on *time*, *quality*, and *value*. Thus, apparel companies are beginning to seek *reengineering solutions* and an effective harnessing of *information* to meet customer requirements quickly and economically. An apparel manufacturer can utilize AMA as tool for improved organization awareness, a more efficient, effective vehicle for communication, and finally, as a basis for cost/benefit analysis of capital investments.

1.3 Research Methodology

An understanding of how a complex system functions can be obtained through models. Models can also be used to communicate the conceptual design of a desired system to those responsible for implementing and maintaining the system. A model, which is a meaningful abstraction of a real-world system, captures only those aspects of a system's functioning that are relevant to the purpose that the model serves. Models that are developed to represent the relevant aspects of a system, together or individually, are referred to as the *architecture* of the system.

A set of models consisting of function, information and dynamics models has been identified as a comprehensive representation of the enterprise for implementing CIM. These three models of an apparel enterprise have been developed to serve as an architecture for a CIM system for apparel manufacturing (AMA). The *function model* provides a representation of the functional components that constitute the enterprise, and the interconnections between these components. The *information model* defines the structure of the information that the enterprise maintains to support its functions. It provides a schema based on which the information system needed to support CIM can be designed. The *dynamics model* captures the time varying behavior of the functions and information in the enterprise and provides the means for analysis of the enterprise CIM system through simulation. In the CIM system development cycle shown in Figure 1.1, AMA provides the specifications based on which detailed design and implementation of the system can be carried out.

1.4 Research Procedure

The development of AMA was carried out in three phases. In the first phase, the scope of the architecture was defined. Next, the AS IS model of an existing enterprise within the defined

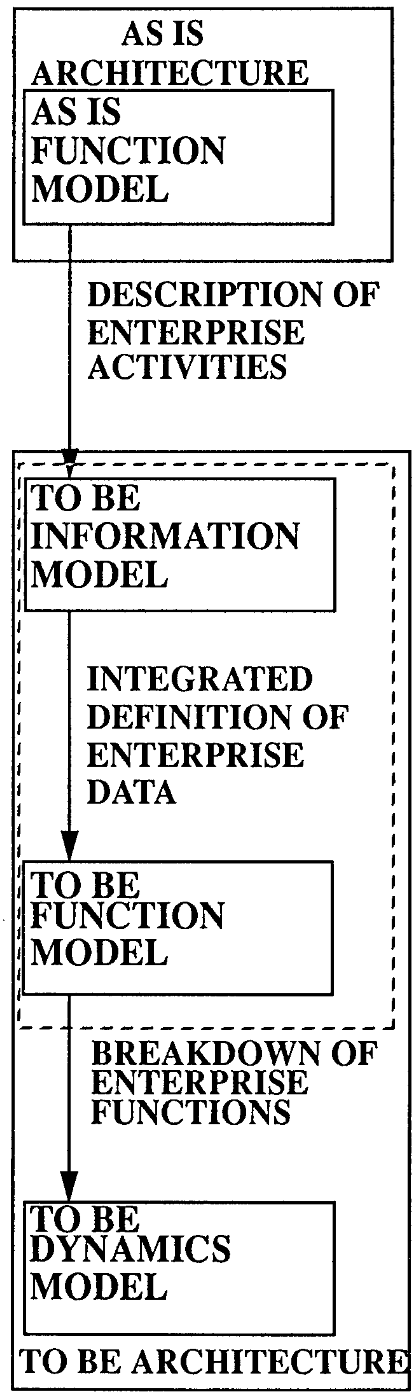

Figure 1.1. CIM System Development Cycle

scope was developed. In the third phase, the AS IS model was used as the basis for developing the AMA which represents a completely integrated apparel enterprise [Jayaraman90 & Malhotra90].

1.4.1 Scope of the Model

The scope of the architecture is stated in terms of the objectives of the modeling activity (*purpose*), the boundaries of the domain under consideration (*context*) and the perspective from which the domain is seen for modeling purposes (*viewpoint*). The scope needs to be stated clearly to avoid cluttering the model with superfluous information that obscures its relevant contents. General information about the apparel manufacturing domain was gathered through literature, plant visits and interviews with people involved in apparel manufacturing. Based on the gathered information and the research objectives, the scope of the architecture was defined.

Purpose: The purpose of the architecture of an apparel manufacturing enterprise is to provide an understanding of the range of activities involved in the day-to-day operations of an enterprise and serve as a blueprint for implementing CIM in the enterprise. The AS IS model serves as the means for understanding how an existing enterprise functions whereas the AMA models make up the architecture for a CIM system for apparel manufacturing.

Context: A primary consideration in the development of the architecture is that the architecture be representative of the general operational characteristics of the apparel industry. For this purpose, the approach adopted for AS IS modeling was to thoroughly study and model one representative enterprise (Oxford Slacks, Monroe, Georgia), have the model reviewed by a broad cross-section of the industry and refine it for correctness and completeness. Trouser manufacturing was chosen as the initial target domain because trouser manufacturing represents generic apparel manufacturing domain well and real-world data for this domain was made accessible by the industry partner. Subsequently, this trouser model was extended and AMA is a *generic* architecture that is applicable for all garments. Activities ranging from marketing and product development to finished goods distribution are included in the context.

Viewpoint: Based on a preliminary analysis of the apparel industry, the activities performed by an apparel manufacturing enterprise were divided into three main categories:

1. *Strategic* decision-making related to the long-term strategy of the enterprise. This function is performed by corporate management. Investment and expansion decisions are examples of long-term decision-making.

2. *Tactical* decision-making related to the day-to-day workings of the enterprise. These decisions are made by the middle level management (e.g., departmental and plant managers). Examples of these decisions are production planning, inventory management, manufacturing, quality control, etc.
3. *Operational* activities whereby the tactical decisions are implemented. For example, the activities involved in assembling a garment fall into this category.

The model takes the viewpoint of middle level managers responsible for day-to-day decisions in the enterprise. Strategic decision-making activities were excluded from the model since the outcome of these decisions are policies that usually do not change on a day-to-day basis. Thus the viewpoint of the model was restricted to tactical decision-making and operational functions of the enterprise.

CHAPTER II

AMA: THE FUNCTION MODEL

The AMA Function model, developed using the $IDEF_0$ methodology, provides the functional structure for a CIM system for apparel manufacturing. The model represents the functions of an apparel manufacturing enterprise as distributed components of a CIM system. The data interfaces between the functions were modeled using the data definition from the AMA Information model.

2.1 Model Syntax and Conventions

The model consists of a set of indexed diagrams and an accompanying glossary of terms. The diagrams model the enterprise in terms of the functions that the enterprise performs and their inter-connections. Functions are represented as boxes on the diagrams and described by short verb phrases [ICAM81a]. Each diagram contains from 3 to 6 boxes thus maintaining clarity and readability. All the interfaces to a function are represented by labeled arrows which connect to the rectangular function boxes from all four sides (Figure 2.1). The arrows from the left (*inputs*) represent inputs to a function and the arrows coming out from the right (*outputs*) represent the outputs that the function produces by transforming its inputs. The entities that constrain or control this transformation of inputs to outputs are represented as arrows coming in from the top (*controls*). The arrows coming in from the bottom (*mechanisms*) represent the mechanisms, i.e., the means used to perform the function. The interface arrows are also referred to as ICOMs and are described in detail in the AMA Function model glossary. Outputs from one function can be inputs or controls for other functions. Arrows connecting function boxes represent interfaces between functions.

Where more detail on a particular function (represented as a box on a diagram) is desired, that box is decomposed on another diagram to depict its sub-functions, interfaces and inter-connections. Thus the diagrams are tied in a hierarchy in which the higher level diagrams contain more abstract functions and the lower level ones go into greater details of each activity. Each diagram is

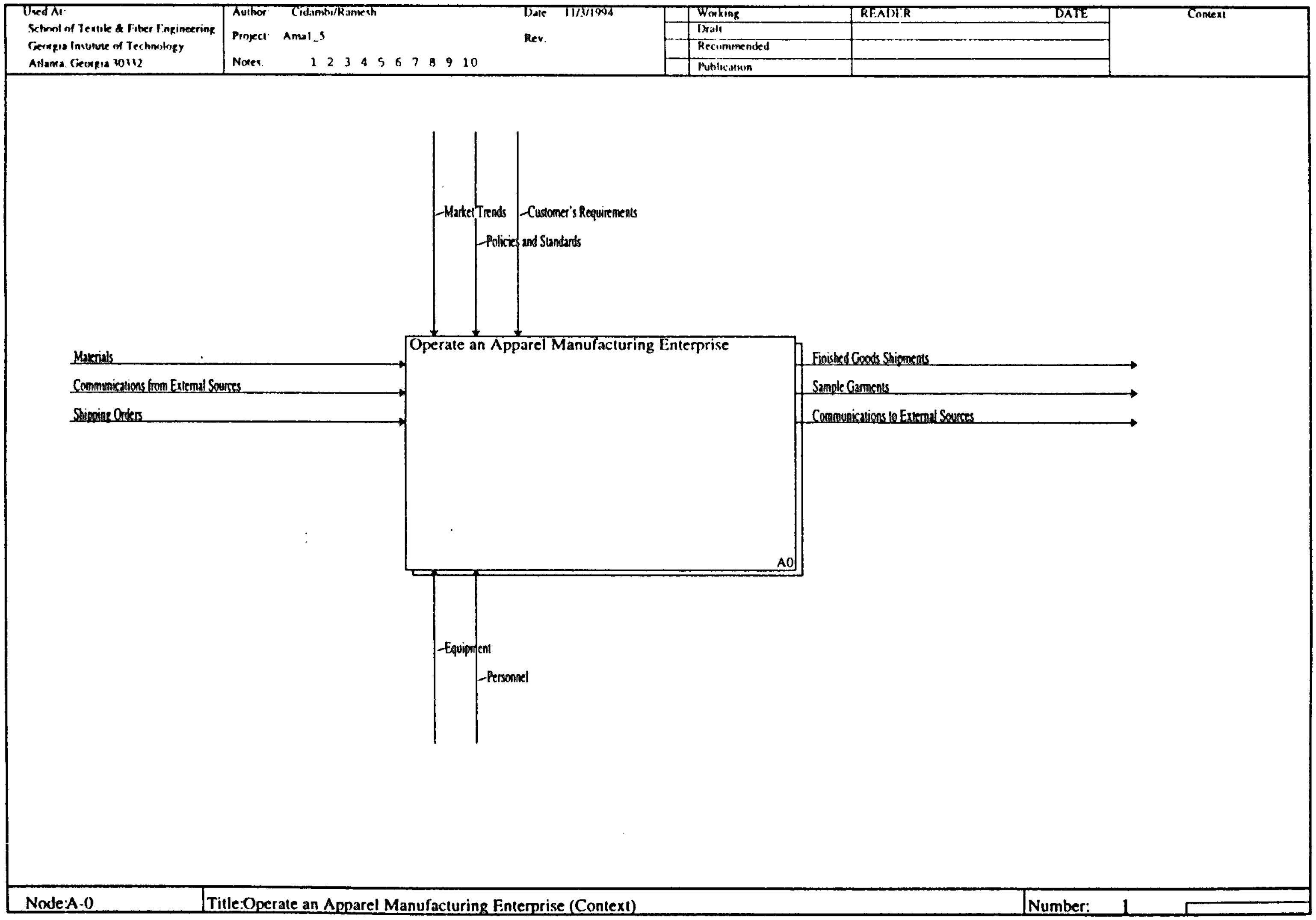

Figure 2.1. The A-0 Context Diagram of the AMA Function Model

bound by the context of its parent function box, i.e., all the arrows on the parent box connect to the arrows in the corresponding child diagram. The model hierarchy converges to a diagram at the top called the model context diagram which contains a single box and its interfaces. The interfaces represented in this diagram serve as the context for the whole model.

A node numbering scheme is used to number the diagrams and boxes. The context diagram is numbered A-0 (A minus zero) and is decomposed into the A0 diagram depicting the major functions of the enterprise. Within a diagram, the boxes are numbered starting with number 1. The node number of a diagram is derived by appending the number of the box that the diagram details to the node number of the diagram in which this box belongs.

2.2 The Function Model

In the AMA Function model, the enterprise functions are represented as functional components of an enterprise-wide information system that create, modify and reference data. Functions that transform physical entities, e.g., *Cut Fabric*, are abstracted as information processing functions that modify the data representing the state of the physical entities. Thus, the ICOM interfaces, in addition to representing inter-connections between the functions, also represent the interface of the functions to the enterprise-wide CIM information system. The model complements the AMA Information model in defining an architecture for a distributed CIM information system in that it identifies the enterprise functions that require access to each data entity defined in the AMA Information model.

In the A-0 diagram shown in Figure 2.1, the inputs to the enterprise are denoted by the arrows to the left of the box. The enterprise receives inquiries from the customer on new products, designs and styles, and it in turn responds to the requests. It receives sales contracts and shipping orders from the customer while materials (e.g., fabric and trim) are received from suppliers (materials may be returned if they do not meet quality standards). The operation of the enterprise is constrained or governed by market trends, industry standards and practices and the requirements of the customer. The resources or mechanisms responsible for the operation are humans and machines. The outputs from the enterprise are sales presentations, samples and shipment of finished goods to the customer, and communications with suppliers and vendors regarding materials and processes.

2.2.1 The A0 Diagram

The A0 diagram clearly identifies the six major functions performed in the day-to-day operations of the enterprise. Since it provides a complete description of the model (including the interactions between the various functions), the A0 diagram is commonly referred to as the top level diagram. All the inputs, outputs, constraints and mechanisms on the A-0 diagram connect to their corresponding boundary arrows on the A0 diagram (Figure 2.2).

The first function (*Develop and Market Product Line*) is to develop the garment for manufacturing and it is based on customer needs and market trends. Materials are procured from suppliers to produce samples. The other results (outputs) of this activity are garment designs and sales presentations to customers.

The activities in product design and other functions in the enterprise require some support (identifying material suppliers, creating quality assurance standards, etc.) and this is captured in the second function, *Provide Enterprise Support Services*. Once the customer places an order, the next function is to plan and prepare for manufacture and this is represented by the third box (*Plan and Prepare for Manufacture*) in the A0 diagram. This activity can be performed only if sales contracts have been finalized and the availability of materials ensured. Hence, prior to developing a sales plan, it would be necessary to develop vendors. This activity is carried out by the *Provide Enterprise Support Services* function. The plan and prepare for manufacturing activity is constrained by the customer's delivery requirements. The outputs of this activity include the cutting schedule for the orders, communications with vendors regarding materials, and markers and materials from warehouse.

The fourth box (*Monitor and Control Production Activities*) represents the monitoring function, which is concerned with monitoring and control of production activities. It generates the production schedule for manufacture of the garment. The fifth box (*Manufacture Garments*) represents the manufacturing function which encompasses cutting, sewing, finishing and garment inspection. It requires markers, materials, and warehouse tickets and cartons as inputs and is constrained by the cutting schedule and the size/color distribution. The main output of this activity is the manufactured garment.

Another major function performed in an apparel enterprise is the distribution of the finished goods and this is represented by the sixth box (*Distribute Garments*) in the A0 diagram.

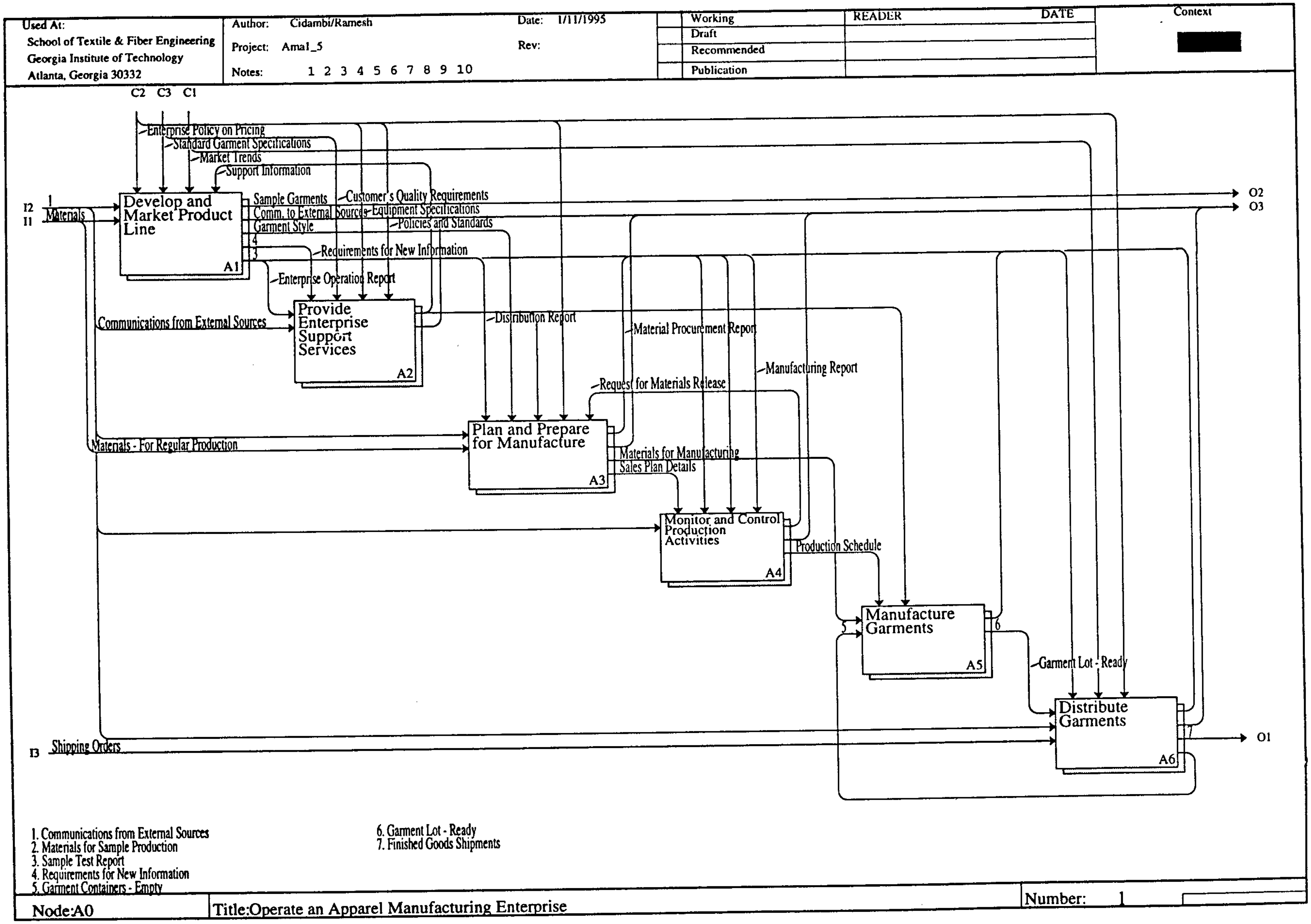

Figure 2.2. The Top Level Diagram of the AMA Function Model

Information about the various functions is vital for the efficient operation of the enterprise. Consequently, every function generates information on its performance (e.g., production data, quality problems, operation reports) as one of its outputs. This information is monitored and utilized for setting standards and providing data for the operation of the enterprise. This function is represented by the second box in the A0 diagram. It is constrained by industry standards and practices in wages, engineering and quality (benchmarking data).

The mechanisms are shown only at the lowest level in the function hierarchy where they are relevant.

2.2.2 The Function Hierarchy

In the A0 diagram in Figure 2.2, the six functions -- A1 through A6 -- correspond to the six functional areas into which the AMA Information model is divided. Each of these functions creates and modifies data entities modeled in the function views in its respective functional area. From the viewpoint of a function, there are two types of data entities: *shared* and *local.* Only those data entities that are of use to other functions are shared by a function; the rest are viewed as local data entities that are unavailable to the outside functions. For example, the function *Develop and Market Product Line* (A1) is viewed as a function that creates and modifies a garment style based on customer's requirements (Figure 2.3). An outcome of this activity is a garment style which is shared with other functions. A style has components, such as construction detail, pattern, fit and process plan, which are created and modified by the sub-functions of A1. Data on all these components are maintained locally within A1 and are not available outside it. Only those patterns, construction details, fit and process plans that have been assigned to the styles represented by the output of A1 are shared with the outside functions. The output interface *Garment Style* of function A1 is defined in the model as a style that has been validated. This constraint in the definition of garment style applies to the shared information as well. Therefore only the validated styles are available outside A1.

The distinction between local and shared data is made for functions at all levels in the model hierarchy. For example, consider the sub-functions of A1. The data on style concepts generated by the stylist are local to the function *Create and Market Styles* (A11). Only those style concepts that have been selected by the customer for development into styles are shared by this function with *Develop Garment Style* (A12). Similarly, data on sample production schedules that are

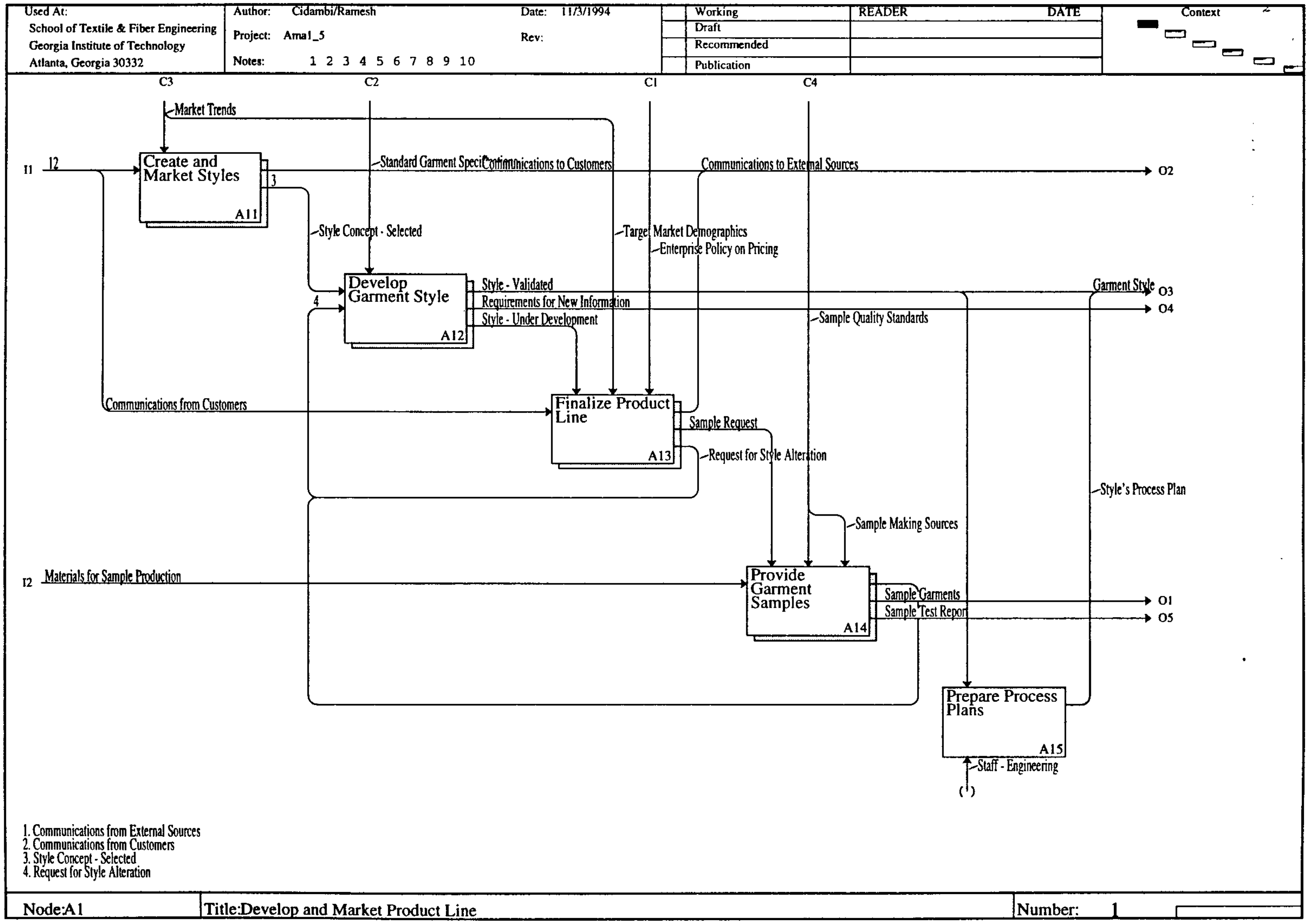

Figure 2.3. The *Develop and Market Product Line* Function

of relevance only to the sample production functions, are local to the function *Provide Garment Samples* (A14).

The output arrows represent the data entities created or updated by a function while the input and control interface arrows represent the data entities referenced by the function. The imported data entities are either referenced or used to generate the outputs of a function. The data accessible to a function are constrained by the definition of the input and control interfaces. For example, consider the function *Develop and Confirm Sales Plan* (A31) which has *Style - Validated* as one of its control interfaces (Figure 2.4). The function requires access to the details of the styles that are to be assigned to the new sales plans. As per the definition of the ICOM *Style - Validated*, function A31 has access to all the data on styles that have been validated. The accessible data entities recursively include the components of the entity style, e.g., data on style would include all the data on the fit of the style and all the data that describe the grade table feature of this fit.

Thus, using the ICOMs, the interface of the functional components of a CIM information system for an apparel manufacturing enterprise is specified in the AMA Function model.

2.3 Text Syntax and Conventions

The text consists of a brief description of all functions and sub-functions at all levels in the model hierarchy. The structure definitions of ICOMs modeled in the AMA Function model are contained in the respective glossary entries. In addition, the ICOMs related to a particular activity are defined in the text for those activities which are at the lowest level of the function hierarchy. The structure definition corresponding to a particular concept (input, control, output or mechanism) is also included for these activities as shown in the example *Schedule Production* (Figure 2.5).

In Figure 2.5, the inputs, controls, outputs and mechanisms to carry out the activity *Schedule Production* are listed. Furthermore, the information entity (IDEF$_1$x entity defined in the AMA Information Model) corresponding to a particular concept (input, output, mechanism, or control) is indicated. In Figure 2.5, E48{PRODUCTION_ORDER} is the IDEF$_1$x entity corresponding to the constraint *Production Order - Scaled.* Looking at entity E48 in the AMA Information model, it can be deduced that *Production Order - Scaled* has the same structure and attributes as PRODUCTION_ORDER as it is a production order with spreading information and marker at-

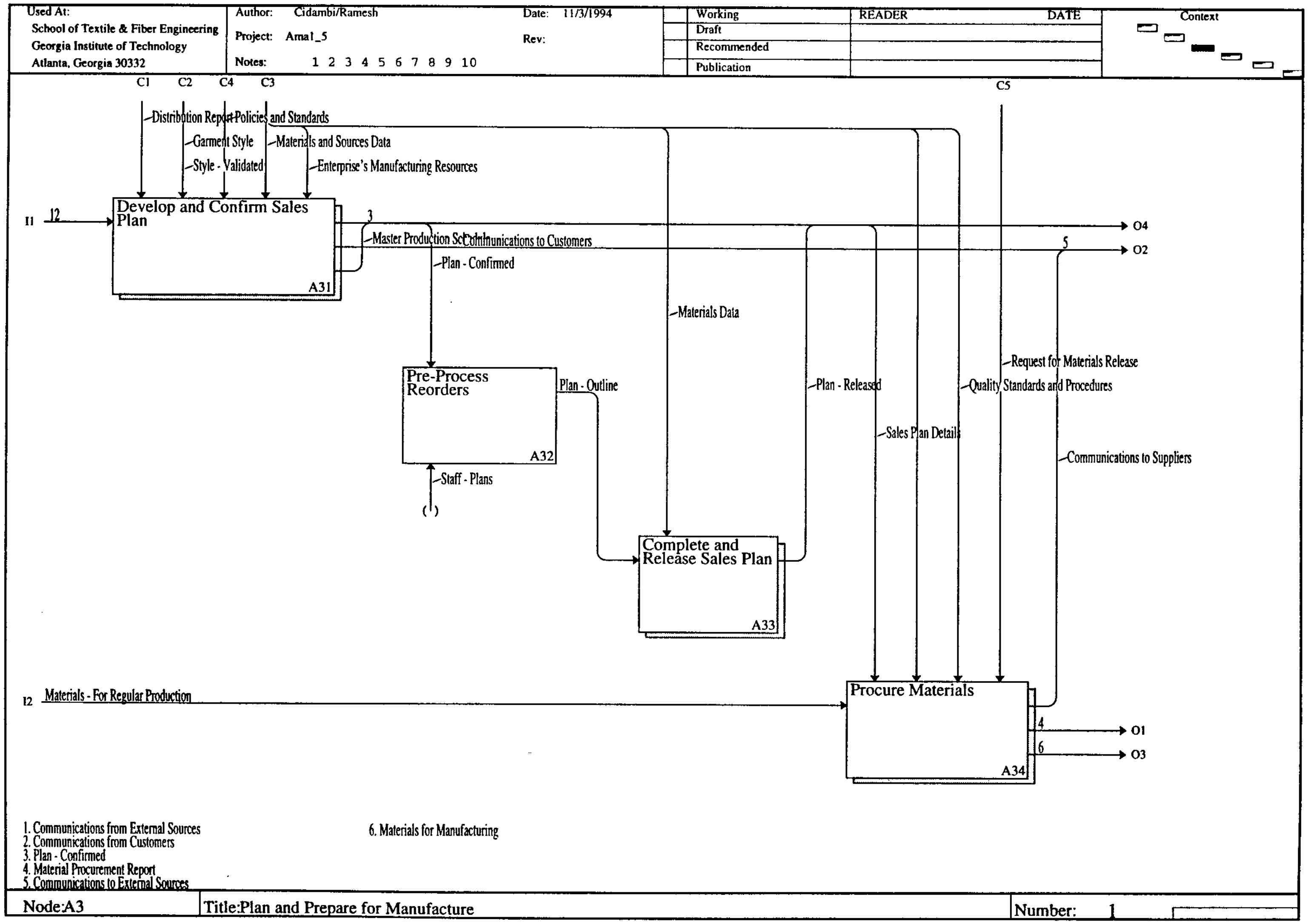

Figure 2.4. The *Plan and Prepare for Manufacture* Function

```
Schedule Production
 Description:
          Schedule production orders for each manufacturing plant and
release the plant schedules at the beginning of each manufacturing period.
Also send a request for release of materials for each order scheduled.
 Interface:
          C1:       Production Order - Scaled;       [E48{PRODUCTION_ORDER}]
          C2:       Manufacturing Report;            [E48{PRODUCTION_ORDER}]
          O1:       Request for Material Release;    [E48{PRODUCTION_ORDER}]
          O2:       Production Schedule;             [E75{PLANT_SCHEDULE}]
          M1:       Staff - Production Control;      [E94{SAL_EMPLOYEE}]
```

48 PRODUCTION_ORDER

Production Order is an order issued to manufacturing plants to produce garments. Exact number, fabric type and size distribution are specified. Various other pieces of information required to determine what exactly is to be produced are also provided.

Primary Key Attributes

ProdOrdNo: *Production Order Number* is the serial number assigned to the production order.

Non-key Attributes

PlanSeqNo: FK SALES_PLAN (45).

QualRepNo: FK QUALITY_REPORT (83).

MarkerNo: FK MARKER(51).

PrOCutDate: *Production Order Cut date* is the date by which the fabric for the production order should be cut.

PrOReadyDate: *Production Order Ready Date* is the date by which the goods should be ready for delivery.

PrOScale: *Production Order Scale* is the multiplying factor for converting size scale ratios to actual quantities to be produced in each size.

PrOSpeInstr: *Production Order Special Instructions* are the instructions accompanying each order. For example, the order may instruct the cutting department to cut only the specified quantity, or to cut according to the available fabric length.

PrOrdStat: *Production Order Status* specifies the status of processing of the order. The status is updated after the completion of each processing phase. Cutting, sewing, finishing, Receiving in the warehouse and stocking are examples of processing phases through which the order goes.

Figure 2.5. *Schedule Production:* Description and Interface.
Entry for entity E48{PRODUCTION_ORDER}
in the AMA Information Model.

tached. Thus the ICOM interfaces, in addition to representing inter-connections between the functions, also act as a link between the function and information models of the AMA.

2.3.1 Type Classification of ICOMs: In the AMA Function model, there may be ICOMs that represent direct exchange of transient information between functions. For example, ICOMs may rep-

resent start, stop and acknowledge signals that are sent from one process to another as part of a hand-shaking protocol. Data on such transient entities need not be maintained in the enterprise information system as it ceases to be of interest once it has been used by the receiving function. Consequently, transient entities are not included in the information model. In AMA, ICOMs are classified as *transient* or *persistent*, based on the type of entities they represent. In the AMA Function model glossary, transient ICOMs are identified by letter 'T' and persistent ones by letter 'P' under the heading Type in the glossary entries for the ICOMs (Figure 2.6). Another classification of the ICOMs results from the fact that ICOMs may represent abstract ideas or knowledge that cannot be defined as structured data in the information model. For example, the knowledge about fashion trends constrains the garment design function, but is difficult to represent this knowledge as structured data. ICOMs representing unstructured entities are classified as free-form ICOMs and are not assigned any data structures in AMA. The type code for free-form ICOMs is 'F' and for structured ICOMs is 'S' as shown in Figure 2.6.

Restart Signal
Type: S/T
Structure:
(Workstation);
Description:
Signal sent to a spreader to restart operation after the defect condition that caused the stoppage has been rectified.

Market Trends
Type: F/P
Structure:
None;
Description:
Fashion trends for the season.

Production Schedule
Type: S/P
Structure:
E75{PLANT_SCHEDULE};
Description:
Schedule for production (assembly and finishing) plants for a particular production period.

Figure 2.6. Glossary Entries for *Restart Signal, Market Trends & Production Schedule*

CHAPTER III

AMA: THE INFORMATION MODEL

The AMA Information model was developed to serve as the database schema for the apparel CIM system. The model provides a coherent definition of the data maintained by the enterprise, based on the semantics of this data. The information model, developed using the $IDEF_1x$ methodology [ICAM81b], consists of a set of entity-relationship diagrams and a data dictionary. Entities about which data are maintained, their attributes and the relationships between these entities were identified from the glossary of the AS IS architecture and represented graphically on the diagrams. Definitions of the entities and their attributes are provided in the data dictionary.

3.1 Model Syntax and Diagramming Conventions

The AMA Information model consists of a set of diagrams and an accompanying glossary. The diagrams depict the information structure in a graphical form as a map of data entities and their relationships, and the glossary provides a textual description of the data entities. The various model elements are represented graphically using the following diagramming conventions:

3.1.1 Entity

Entities are represented by rectangular boxes in the Information model. Each entity is given a unique name and number that appears at the top of the box. For example, the box representing the entity *pattern* is labeled E14/PATTERN (Figure 3.1).

3.1.2 Relationship

The relationships between entities are represented by directed lines joining the related entities. For example, the relationship "A pattern consists of many parts" is expressed as a line directed from E14/PATTERN to E15/PATTERN_PART (Figure 3.1). The dot at the end of the line is

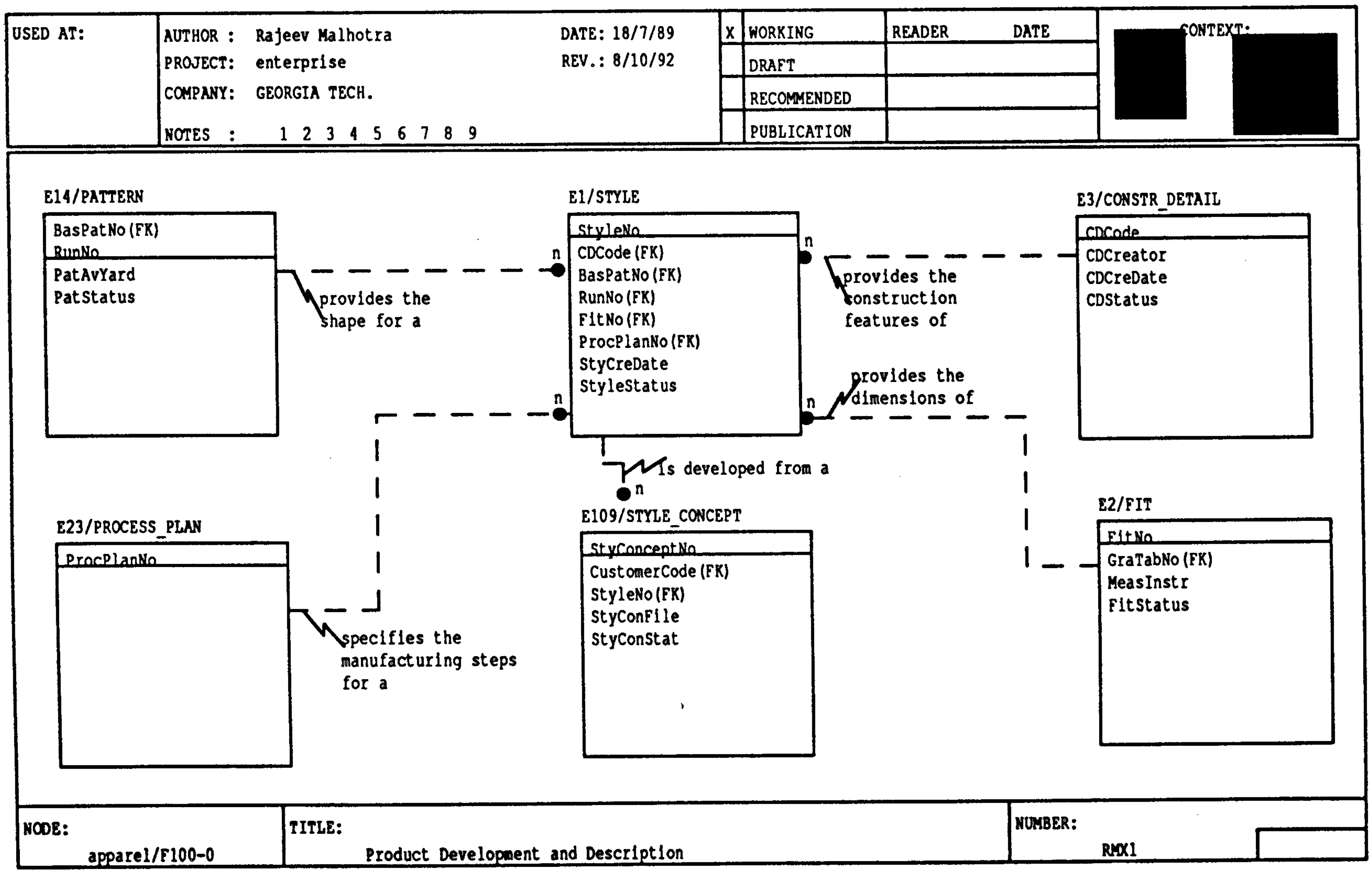

Figure 3.1. IDEF$_1$x Entity-Relationship Diagram

used to indicate the direction and letter *n* next to it represents the cardinality of the relationship, which is *one-to-many* in this case (i.e., a pattern consists of many parts whereas each part belongs to only one pattern). A parent-child relationship is said to exist between pattern and pattern part in which pattern is the parent and pattern part is the child.

3.1.3 Attributes

The characteristics that describe the entities are represented as attribute names and are listed inside the entity boxes. The attributes listed above the horizontal line dividing the entity boxes make up the primary key of the entity. The primary key uniquely identifies an instance of an entity. For example, each pattern is uniquely identified by its primary key consisting of attributes *BasPatNo* and *RunNo.* Attributes listed below the line are called non-key attributes. When a relationship exists between two entities, the primary key of the parent is inherited by the child as a foreign key. A foreign key is denoted by FK in parentheses after the inherited attribute name. For example in Figure 3.1, the attribute, *BasPatNo,* which is a part of the primary key of the entity, *pattern,* is inherited from its parent entity, E13/BASE_PATTERN.

3.1.4 Dependent Entities

For an instance of an entity to exist, it must have values for all its primary key attributes. For example, a base pattern's record cannot be maintained in the enterprise without assigning a value for its BasPatNo. Therefore, a base pattern does not exist on the records if it does not have a BasPatNo. If the primary key of an entity is inherited, as in the case of E14/PATTERN (Figure 3.1), then the existence of such an entity depends on the existence of its parent(s). For example, a pattern that belongs to a base pattern type identified by BasPatNo 231 cannot exist in the database if there is no record for a base pattern with BasPatNo 231. A dependent entity is represented as a box with rounded corners and a dependence relationship is represented by a solid line.

3.1.5 Categories

Some information entities are related by their similarity to each other. For example, construction materials, such as trim, labels, thread, etc. are identified by a material code and a color code, but each has certain characteristics that are unique to it. For example, count may be an im-

portant characteristic of thread but it has no meaning for labels. The relationship among such entities is called a categorization relationship and is illustrated for entity E34/MAT_VARIANT.

3.1.6 Functional Views

While modeling a complex system such as an apparel manufacturing enterprise, it is difficult to map all the relationships on a single diagram. For ease of modeling, the model is broken up into functional views, each of which represents a particular aspect of the enterprise operation. These views remain parts of the same model because they share common entity definitions. Each functional view can be spread over multiple diagrams that are connected through *pageconnectors*. The node number and the title of the functional view are printed at the bottom of each diagram.

The information model is normalized to the third normal relational form [Codd70]. In this form, all the many-to-many relationships (e.g., many materials may be ordered on a purchase order and a material may be ordered through many purchase orders) are transformed into one-to-many relationships by creating intermediate child entities between entities that have many-to-many relationships, and the non-key attributes of each entity are dependent only on the key attributes of that entity and nothing else. All the entities and their attributes are defined in the dictionary that accompanies the model.

3.2 The AMA Information Model

The AMA Information model defines the structure of the entities generated and processed by the functions of the apparel manufacturing enterprise and the relationships that exist between these entities. It represents the following functional views:

1. Marketing and Product Development
2. Enterprise Support Services
3. Planning and Preparation for Production
4. Production Control
5. Manufacturing
6. Distribution.

The AMA Information model spans all the enterprise functions that fall within the defined scope of the architecture.

3.2.1 Marketing and Product Development

The Marketing and Product Development function involves marketing of product ideas to customer and development of garment style. The result is an unambiguous description of what the garment looks like and how it is to be made. A style is developed for a customer from the style concept (a sketch, garment sample, etc.) which describes the customer's style requirements. The function view *Product Development and Description* depicts the structure of the entity *style* and its relationships to its constituent entities, i.e., construction detail, pattern, fit and process plan. The view also depicts the relationship between a style and a style concept.

The structures of construction detail, pattern, fit and process plan are defined in separate functional views. For example, the structure of construction detail is defined in the function view *Construction Detail.* Construction detail provides the description of garment features, such as front pockets, waistband, base, etc. The construction detail also specifies the types of materials to be used for constructing the garment features and instructions regarding their placement. It serves as a bill of materials for the garment. It is a list of feature items selected from a library of features. Materials for each feature item are specified while describing the item. Only the type of material is specified during style development stage since the color of the materials is different depending on the fabric used to make the garment. Colors for each material are specified at a later stage for each fabric to be used when the fabric colors are known. The manufacturing cost of the garment is determined by summing up the cost of materials used and the cost of operations associated with each garment feature.

3.2.2 Enterprise Support Services

The following support service functions fall within the purview of this model: Vendor development, technology evaluation, human resources management, industrial engineering and quality control. The information generated and maintained by these services is used by other functions, such as product development, procurement and manufacturing. This information pertains to raw materials and their sources, manufacturing operations and resources, and quality standards and procedures. Data maintained on materials, which includes the description of the materials, their standard costs, the colors in which the materials are available and the sources for the materials, are modeled in the function view *Material Description.*

The resources of the enterprise and their capabilities are also modeled. For example, the data on equipment is modeled in the function view *Manufacturing Resources - Human.* The data on operators includes the operator's identification number, name, plant and department, skill level and capabilities. The entity *job* defines the skill level of operators. The operations that an operator has been trained to perform are modeled as the entity *operator skill.* Information maintained about each operation includes its description, standard time required to perform the operation, standard cost attributed to the operation and the skill level required to perform the operation.

3.2.3 Planning and Preparation for Production

Production planning activities include master planning for production and procurement of materials. Sales orders received from customers are central to the planning activity and are modeled as the entity *sales plan* in the function view *Sales Plan Description.* A sales plan is instituted for the production of garments belonging to a particular style. In a sales plan, the number of garments to be produced using each fabric is specified by the customer or is based on POS data for brandname products. The customer or merchandising department also provides the delivery schedule for the plan. For example, a sales plan may be instituted for the production of 10,000 trousers of a particular style - 2,000 of them in navy blue twill and the remaining 8,000 in khaki canvas. The customer may specify that 40% of the order be ready for delivery by November 1st and the remaining a month later. The sales plan may not specify the size distribution of the order. The size distribution is not required for the master planning stage. Planning and preparation for production involves allocation of available production capacity to the product line, assignment of colors for materials and ordering of materials for the plan. On the master schedule, a part of the available production capacity is reserved for a plan. The production plant is selected based on the available capacity and capability to produce a particular style. Production periods are selected to match the delivery schedule provided by the customer.

3.2.4 Production Control

Production control involves planning and release of production orders to manufacturing plants; the data maintained to support this activity are modeled in the function view *Cut Order Planning.* A production order is issued by production control to manufacturing for producing the specified quantity of garments in a given color and size distribution towards the completion of a

sales plan. Production for a sales plan is completed through one or more production orders. A marker, consisting of an arrangement of sections, each of which is packed with graded pattern parts for one or more sizes, is assigned to a production order. As part of cut order planning, the spread layout is also created. The spread layout specifies the number of layers of each fabric type/color that should be spread under each marker section to yield the desired number of garments in each size and color, and is modeled as the entity *spread section.*

Production orders are prepared and released after taking into account the finished goods inventory, inputs from customer regarding size and color distribution, and availability of raw materials and production resources. Each manufacturing plant has a schedule on which the orders released for production at that plant are posted. Such a schedule may be prepared and released on a weekly or biweekly basis. Each manufacturing plant receives its production schedule whereas a centralized cutting facility receives the schedules for all the plants it serves.

3.2.5 Manufacturing

Manufacturing of garments involves cutting, sewing and finishing. Cutting for production orders is scheduled in such a way that the production schedule prepared by the production control function can be followed. The cutting facility collects all the fabric parts and other materials required to produce garments for a production order and ships this package to the appropriate plant for further processing. The fabric parts are labeled after cutting so that the parts belonging to any one garment can be easily identified.

In the manufacturing plants, each scheduled production order is assigned groups of equipment on which the garments are assembled and finished. A group may be a line or a module. Each group is assigned a set of operations and operators. For example, four modules may be assigned for a production order, one each for trouser front assembly, back assembly, final assembly and finishing. The operations assigned to each equipment group are specified in terms of process steps on the *process plan* for the style.

3.2.6 Distribution

Distribution of finished garments to customers involves stocking of goods received from the plants, retrieval of appropriate garments for shipping, and packing of these goods. The entities supporting stocking of finished goods are modeled in the function view *Finished Goods Warehous-*

ing. Regular quality finished garments are stored in small containers each of which contains one or two dozen garments of the same color and size. Irregular garments are collected together in large bags and are not stored with regular garments in the warehouse, but are moved to a special area in the distribution center for disposal. Containers with regular quality garments are divided into groups for storage since a single storage location may not be large enough to hold all the containers for an order. Each location may hold groups from many production orders.

Garments produced for a sales plan are shipped to the customer only when shipping orders are received from the customer. A shipping order specifies the mix of colors and sizes of the ordered style. Typically, a customer sends a shipping order for each retail outlet. Garments for each shipping order are packed individually in shipping cartons and shipped either directly to the retail outlets or to distribution points specified by the customer. To facilitate packing and shipping, all the shipping orders for a sales plan that have to be shipped around the same time are consolidated into a single packing order and garments required for these orders are retrieved together.

Thus, the AMA Information model provides a single integrated definition for the apparel enterprise data. This definition is the conceptual schema for an enterprise-wide information system that can support information sharing.

CHAPTER IV

CONCLUSION

An architecture consisting of a set of models that provides the specifications of a CIM system for an apparel manufacturing enterprise has been developed. A methodology suited to the specific needs of CIM system modeling has been presented and used to develop the architecture for an integrated apparel enterprise.

Central to CIM is an enterprise-wide information system, that supports interactions between enterprise functions through information sharing. The AMA Information model provides a comprehensive definition of the enterprise data suitable for information sharing and serves as the conceptual schema for a CIM information system for an apparel manufacturing enterprise.

The AMA Function model, provides the function structure of an apparel enterprise in which the functions interact with each other through the enterprise-wide CIM information system as defined by the AMA Information model. In this model, the inputs, controls, outputs and mechanisms for each function have been defined as interfaces to the CIM information system. The functions are viewed as nodes of the distributed information system. The functions maintain the data that they work with locally; the data that a function makes accessible to other functions for sharing is explicitly represented in the model through its output interfaces.

Of the two aspects of CIM, i.e., information systemization and process mechanization, the AMA architecture focuses mainly on the systemization aspect because systemization needs must be clearly identified at the enterprise level *before* mechanization for CIM at the function level can be designed and implemented. The mechanization aspect is addressed in the architecture by developing the specifications for the control and process modules. How these tasks are mechanized and at what level mechanization is implemented are left to the individual enterprise utilizing AMA.

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